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Europe in a 6 Degrees Warmer Climate

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1. Introduction

There is no doubt that a world with an average temperature 6 degrees above pre-industrial climate will be very different from what we currently know; but what will it look like? With the help of a simulation with the ECEARTH global model, downscaled over Europe with the regional model HIRHAM5 in 25km grid point distance, we investigate such a climate.

Through a complementary analysis of CMIP5 GCM results we also study the time at which such a condition may be reached.

One simulation is normally insufficient for a robust analysis of climate change effects. Therefore some work is devoted to an analysis of the extent to which various climate parameters exhibit pattern scaling, i.e. that the change in the relevant parameter is proportional to the change in global temperature. We analyse simulations with the same regional model under weaker climate change, and examine whether the 6-degree simulation scales the same way as these simulations.

2. Method

In this study, targeted simulations have been performed with the HIRHAM5 regional climate model (RCM) for time slices corresponding to around 6 degrees of global warming and for an RCP4.5 scenario, and finally a transient RCP8.5 experiment; these simulations have been driven by the EC-EARTH global circulation model (GCM) and have used the same integration domain as was employed in the ENSEMBLES project (http://ensembles-eu.metoffice.com). In this study, data from these simulations are being compared to the ENSEMBLES RCM database.

To establish the 6-DEG scenario, we performed the benchmark CMIP experiment of idealized 1% per year CO2 increase using the EC-EARTH model (Hazeleger, 2012). The run initialized from the pre-industrial control, and the atmospheric CO2 concentration was prescribed to increase at 1% per year from the pre-industrial value (i.e., 285 ppm) until five times the initial level had been reached, and then kept constant afterwards. The simulation was 250 years with all other forcings kept at the pre-industrial level. As long as the CO_2 increases, the simulated global mean surface temperature rises. It continues to slowly increase for several decades even after the CO2 stops growing, and gradually stabilizes at a level of about 6.5 K warmer than the preindustrial level towards the end of the simulation.

3. Results

Figure 1 shows the absolute changes in seasonal mean temperature and the relative changes in seasonal mean precipitation compared to the 1976-2005 level for a global mean temperature change of about 6K for both summer (JJA) and winter (DJF). We find that the winter temperatures increase from about 5 K in western and southern Europe (British Isles, Iberian Peninsula, France) to more than 9K in the northeast (northern Finland, western Russia). In summer the largest temperature change of more than 9K is found in the Iberian Peninsula and southern France; large changes of 7-8 K are also found along the northern coast of the Scandinavian Peninsula. The lowest temperature increases of about 5-6 K are found in most of Northern Europe, centered on the Baltic Sea, and also including the British Isles. The geographical pattern of these changes is very similar to the changes projected in a 2 K warmer Europe (Vautard et al, 2014), just with a much higher amplitude.

For precipitation we find that in winter the seasonal mean precipitation increases in large parts of Europe, primarily north of 47°N, with the largest changes of more than 60% increase north and east of the Baltic Sea. The largest decrease of 30-50% occurs in the Iberian Peninsula and along the Mediterranean coastline. In summer the line dividing wetting from drying shifts northward; increases of about 20-40% are only found on the Scandinavian Peninsula, in Finland, the Baltic countries and in Russia, with the highest values being in the Norwegian mountains. The largest decreases of 50-60% in seasonal mean precipitation occur in the Iberian Peninsula, southern Italy, Albania, Greece and Turkey. In summary, EC-EARTH-HIRHAM5 projects that particularly in winter, northeastern Europe will get a much warmer and wetter climate, whereas in summer the largest changes will occur in the Iberian Peninsula and along the Mediterranean coast with a much warmer and drier climate. The noticeable changes in winter of much warmer and wetter conditions in northeastern Europe are also visible in a just 2K warmer Europe for the ensemble mean of 14 ENSEMBLES models (Vautard et al., 2014), indicating that this feature is very robust.

4. Scaling with Global Temperature Change

In order to investigate to which extent the climate signals shown here are compatible with pattern scaling, we show in Fig. 2 the average change of several quantities over Scandinavia as a function of the global warming of the driving GCM. All ENSEMBLES regional model results as well as a transient RCP8.5 simulation and time-slice simulations for 6 degrees warming and for RCP4.5 are shown, all with HIRHAM5 for the ENSEMBLES domain, driven by EC-EARTH. It can be seen that pattern scaling works quite well, and we therefore conclude that the 6-degree-warming simulation presented here is not implausible.

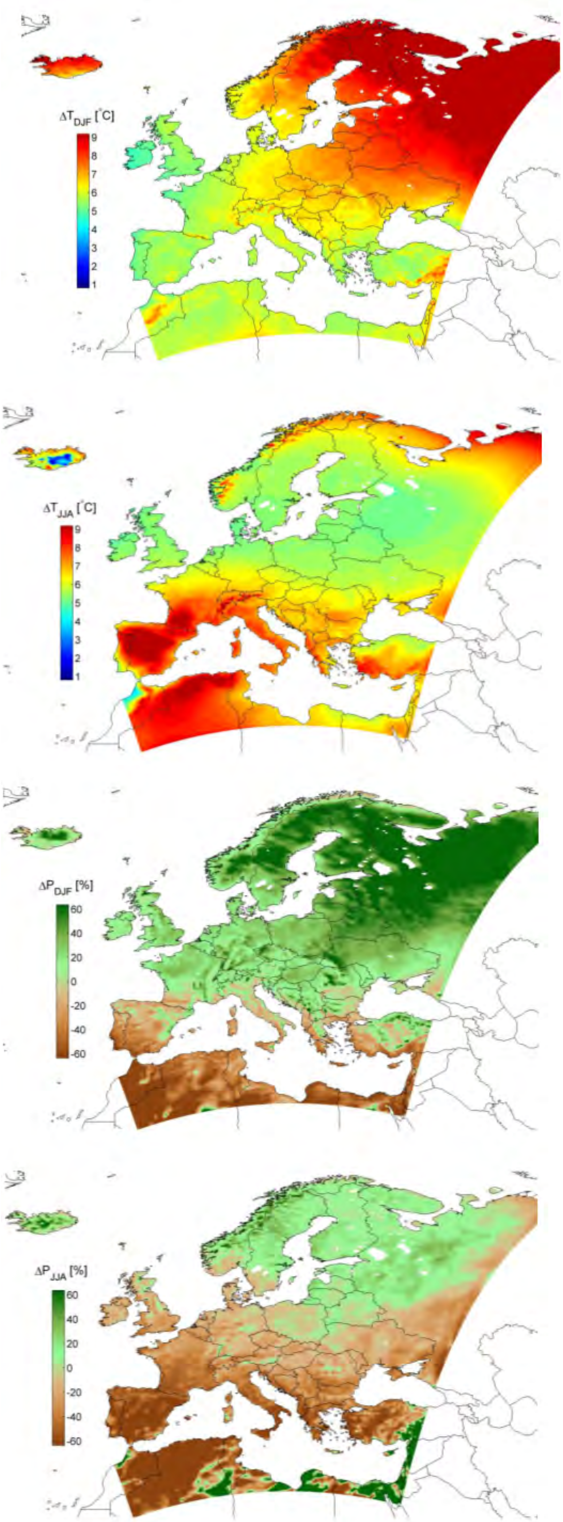

Figure 1 Absolute changes in seasonal mean temperature and relative changes in seasonal mean precipitation compared to the 1976-2005 level for a global mean temperature change of about 6K for summer (JJA) and winter (DJF).

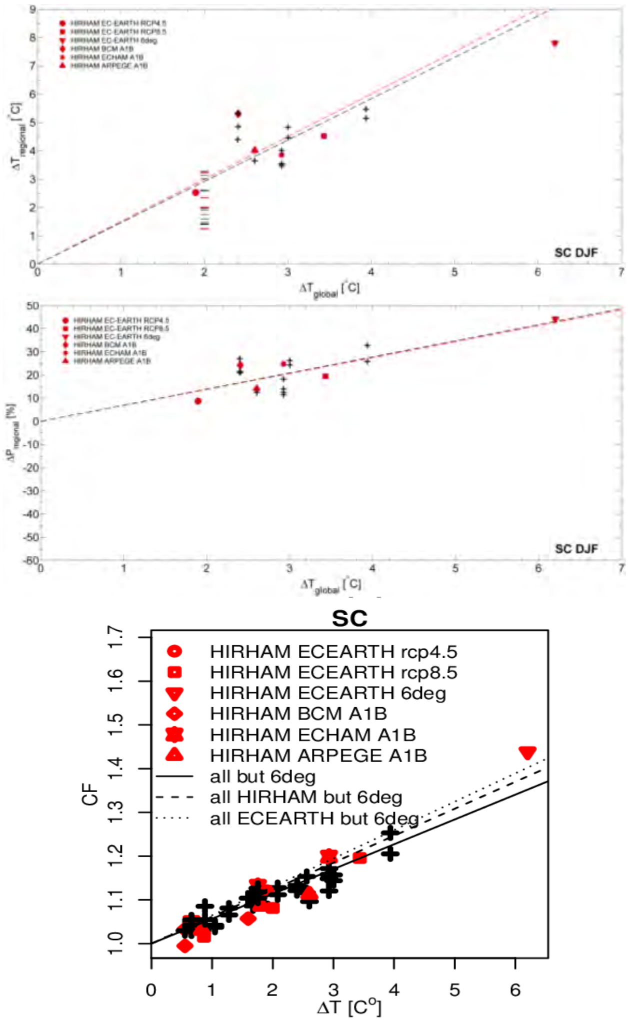

Figure 2 Scaling of climate signal with global temperature change for ENSEMBLES plus several HIRHAM5 simulations. Top panel: Scandinavia winter temperature (K). Middle panel: Scandinavia winter precipitation (%). Bottom panel: 99.9 percentiles of daily precipitation for Scandinavia (roughly 3-year return values; shown as climate factor, scenario divided by control). Red symbols: HIRHAM5. Black crosses: Other ENSEMBLES simulations.

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